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(19)

(54) HEAT RECOVERABLE ARTICLE

(71) We, RAYCHEM LIMITED, a British Company, of Moor House, London Wall, London, E.C.2, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a heat-recoverable article and more especially a heat-recoverable article for the purpose of electrically insulating and covering bus bars for electrical equipment, and to a kit of parts including, and a process employing, the article.

By a heat-recoverable article there is meant one which has been deformed, for example, under heat and/or pressure from an original configuration to a dimensionally heat unstable configuration and which has been caused to remain in said heat unstable configuration, for example by cooling whilst maintaining the pressure, the article being capable of returning to its original configuration upon the application of heat alone.

In the past, bus bars have been electrically insulated by submersion in an oil-filled container or by a covering of polyvinyl chloride material or epoxy resin or resin bonded paper. Such electrically insulating coverings have at best a one minute electric strength of between 10 and 15 kilovolts per mm thickness.

Bus bars submerged in oil operate effectively at up to 11 kV if the next nearest parallel bus bar is at an edge-to-edge distance of at least 25 mm. Oil immersion tanks are however, bulky and heavy and do not facilitate access to the bus bars.

The other mentioned electrically insulating systems require an edge-to-edge separation between bus bars of at least 50 mm if the bus bars are carrying 11 kV operating voltage. Closer placing of the operating bus bars results in corona discharge.

Under short circuit conditions, the temperature of a bus bar may rise as high as 250° C for very short periods of time and the insulation must exhibit effective insulating properties thereafter. Transformer oil can withstand such temperature rises very successfully, but epoxy resins crack as a result of thermal expansion, while non-crosslinked polyvinyl chloride coverings, above a temperature of 100° C, melt and drip off the bus bars.

By the present invention, parallel placing of bus bars operating at, for example, 11 kV with a separation of 40 mm depending on bus bar geometry, is possible, and in certain circumstances an electrical strength of at least 30 kV/mm, when the voltage is applied through the bus bar insulation for one minute, is achieved.

The present invention provides a heat-recoverable hollow article, having at least one open end, which comprises a heat-shrinkable sleeve, at least one portion of the inner surface of which is provided with an electrically conducting liner, such that when the heat-recoverable article is recovered on to a substrate, the electrically conducting liner remains or comes into contact with the sleeve throughout the length of said sleeve portion, so that there are no voids between the sleeve and the liner and the, or at least one, end portion of the inner surface of which sleeve is provided with an electrically insulating sealant.

The present invention also provides a process for electrically insulating a joint between bus bars wherein the heat-recoverable hollow article of the invention is caused to shrink over the joint so that the joint lies within a faraday cage and the sealant provides a barrier against moisture ingress.

The present invention still further provides a kit of parts, comprising the heat-recoverable hollow article of the invention, a tee-shaped metallic bus bar surrounded by an electrically insulating crosslinked polymeric material and heat-recoverable polymeric tubing having a one minute electric strength of at least 30 kV/mm.

The term "bus bar" is herein used to describe what is meant by the terms "bus bar," "bus rod" and "bus shape," the definition of each of which may be found in ASTM B187—74.

In general, a heat-recoverable article such as that provided by the present invention is of a material capable of having the property of plastic or elastic memory imparted thereto and has been expanded under pressure and/or heat to a size greater than its original size and cooled while maintaining its expanded configuration. An article treated in this manner retains an expanded configuration until it is again heated to at least its heat recovery temperature or temperature range when it recovers to or towards its original shape.

Examples of preferred materials useful in forming a heat-recoverable hollow article according to the present invention may be found in British Patent Nos. 1,337,951 and 1,337,952 and 1,303,432, the disclosures of which are incorporated herein by reference. The materials disclosed therein are track-resistant, an advantageous property of bus bar insulation for protection against tracking failure caused by water condensation on the surface thereof.

The electrically conducting liner of the present invention may be of any polymeric material to which the property of electrical conductivity has been imparted by incorporation of quantities of conductive filler, for example, carbon black or metal flakes or powders, for example, silver flake or copper powder. It is essential that during use the liner is in void-free contact throughout its length with the sleeve. To this end it is advantageous for the liner to be a mastic, a hot melt adhesive or a thermosetting adhesive. As mastic compositions there may be especially mentioned poly iso butylene or rubbers, for example, butyl rubber or epichlorohydrin based rubbers to which suitable plasticisers and tackifiers have been added as required. As suitable hot melt adhesive compositions there may be especially mentioned copolymers of ethylene, e.g. ethylene/vinyl acetate, ethylene/acrylic acid. Any of these compositions may include conventional additives, e.g. processing aids and anti-oxidants, as required.

Alternatively, the liner may be of a plastics material not normally regarded as having adhesive characteristics in which a conductive filler has been incorporated. Examples of such materials include polyolefins for example, vinyl chloride, polyvinylidene fluoride and homo-, co- or ter-polymers of hexafluoroethylene. The liner may advantageously be formed from these materials.

A particularly advantageous method of manufacture of the heat-recoverable article according to the invention is dual extrusion whereby the sleeve and the liner are extruded simultaneously and drawn together (for example, as disclosed in British Patent No. 1,033,959). The resulting article may be subjected to irradiation to cross-link it. The depth of penetration of the irradiation may be varied as required so that the material at the dividing line between the sleeve and the electrically conducting liner may be cross-linked to join these two intimately.

A sleeve and a liner may be extruded separately, the liner placed inside the sleeve and bonded securely thereto. The material of the liner and/or of the sleeve may be cross-linked before or after this step and the liner may have the property of plastic or elastic memory imparted thereto as desired.

The, or each, open end portion of the heat-shrinkable sleeve, according to the present invention, is provided with an electrically insulating adhesive, e.g., a hot-melt adhesive, mastic or thermosetting adhesive which is capable of sealing to provide a barrier against moisture ingress under the sleeve through the, or each, end portion thereof. In one form of article, the conducting liner may extend along the total length of the inner surface of the sleeve, the or each end portion of the inner surface of the liner being provided with the electrically insulating sealant.

A tee-shaped, one-piece metallic bus bar provides a very useful replacement for the conventional, perpendicularly jointed bus bar system, since the smooth surface which may result from this substantially reduces corona discharge. Electrical insulation of a tee-shaped metallic bus bar to form one element of a list of parts according to the present invention is provided by a cross-linked polymeric material, moulded in place about the metallic bus bar. The material is advantageously one of those disclosed in British Patent Nos. 1,337,951, 1,337,952 and 1,303,432.

The cross-linked polymeric material of the present invention advantageously has a one minute electric strength of at least 30 kV/mm.

Whilst the article of the present invention is especially useful for the purpose of electrically insulating a bus bar, it may be used equally well for electrical insulation of any other electrical conductor.

Several forms of articles of the present invention will now be described by way of example only, with reference to the accompanying drawings in which:

Figure 1 is an axial sectional view of an article constructed in accordance with the present invention;

Figure 2 is an isometric view partly in section of the view of figure 1 positioned over jointed bus bars;

Figure 3 is an isometric view in section of an article of figure 1 after recovery on to jointed bus bars;

Figure 4 is an isometric view of a cross-linked polymeric article moulded in place on a tee-shaped metallic article.

Referring now to the drawings, figures 1 and 2 show a heat-recoverable article, constructed in accordance with the present in-

vention, indicated generally by reference numeral 1. A heat-shrinkable sleeve, 2, is provided with an electrically conducting liner, 3, and an electrically insulating sealant, 4. As shown diagrammatically in Figure 3, on heating the article, the sleeve, 2, shrinks, and the liner, 3, is forced toward the bus bars, and may be, if desired, caused to melt or soften sufficiently to cause all gaps and irregularities to be filled (not shown for clarity).

The following examples illustrate the invention:

Example 1.

Bolted bus bar joints were electrically insulated and the discharge inception voltage was plotted against the joint-to-earth distance.

Bus bar Joint No.	1.	2	3	4
Insulation Type	None	Polyisobutylene-containing putty	Heat-shrinkable polyethylene-containing tubing	Heat-shrinkable polyethylene-containing tubing
Conductive Liner	None	None	None	Polyisobutylene containing conductive mastic
Sealant	None	None	Butyl rubber adhesive tape	Butyl rubber adhesive tape

The Graph (Figure 5) illustrates the substantial improvement in discharge inception voltage obtained especially at low joint-to-earth distances on insulating bolted bus bar joints according to the present invention, the numbered curves corresponding to the joint numbers above.

Example 2.

Power Frequency Test.

A sample of tubing having the one minute electric strength of at least 30 kV/mm (Raychem BBIT) was heat recovered on a length of bus bar and a conductive paint was applied over 7 cm length of the outer surface of the tubing. A semi-conductive tubing was heat-recovered over the edges only of this paint leaving 5 cm of the paint uncovered. The voltage applied through the bus bar was increased in 5 kV at one minute intervals from 15 kV. The paint layer was earthed. As a comparison, the Raychem BBIT tubing was replaced by a commercially available heat-shrinkable PVC tubing:

Results:

Tubing	Tubing Thickness (mm)	Breakdown Voltage (kV rms)	Breakdown Stress (rms kV/mm)
Raychem BBIT	1.86	70	37.5
Heat-Shrinkable PVC	2.3	35	15

Example 3.

Impulse Withstand Voltage Comparison.

The insulated bus bars were prepared as in Example 2. The impulse voltage was found increasing the voltage in approximately 5 kV steps, 10 pulses being applied at each test level. A positive polarity 1/50μ sec. pulse was used in accordance with the test B.S. 923, 1972.

Results:

Tubing	Tubing Thickness (mm)	Withstand Voltage kV (Impulse)	Withstand Stress (peak kV/mm)
Raychem BBIT	1.9	105	55
Heat-shrinkable PVC	1.98	60	30

The results from Examples 2 and 3 show that surface-to-surface separation of bus bars may be reduced using material which has improved breakdown and impulse withstanding properties.

WHAT WE CLAIM IS:—

1. A heat-recoverable hollow article having at least one open end comprising a heat-shrinkable sleeve at least one portion of the inner surface of which is provided with an electrically conducting liner, which liner, upon recovery of the article onto a substrate, remains or comes into void-free contact with the sleeve throughout the length of said sleeve portion and the, or at least, one, open end portion of the inner surface of the article is provided with an electrically insulating sealant.

2. An article as claimed in claim 1 wherein the material of the sleeve is cross-linked.

3. An article as claimed in claim 1 or 2 wherein at least the outer surface of the sleeve is track-resistant.

4. An article as claimed in claims 1 to 3 wherein the total length of the inner surface of the heat shrinkable sleeve is provided with an electrically conducting liner and the or each end portion of the inner surface of the liner is/are provided with an electrically insulating sealant.

5. An article as claimed in claims 1 to 3 wherein the central portion of the inner surface of the heat-shrinkable sleeve is provided with an electrically conducting liner and the, or each, end portion of the inner surface of the sleeve is/are provided with an electrically insulating sealant.

6. An article as claimed in claims 1 to 5 wherein the electrically conducting liner is of a polymeric material and has been rendered electrically conducting by the incorporation of an electrically conducting filler.

7. An article as claimed in claim 6 wherein the polymeric material of the electrically conducting liner is a mastic, a hot melt adhesive or a thermosetting adhesive.

8. An article as claimed in claim 6 wherein the polymeric material of the electrically conducting liner is cross-linked.

9. An article as claimed in claim 8 wherein the electrically conducting liner is heat-shrinkable.

10. An article as claimed in claims 1 to 9 wherein the electrically insulating sealant is a mastic, a hot-melt adhesive or a thermosetting adhesive.

11. An article as claimed in claim 1, substantially as described in Example 1.

12. An article as claimed in claim 1, substantially as hereinbefore described with reference to and as illustrated by Figures 1 to 3 of the accompanying drawings.

13. A process for electrically insulating a bus bar joint wherein a heat recoverable article as claimed in any one of claims 1 to 12 is heat recovered over the joint and the sealant seals against moisture ingress.

14. A kit of parts comprising a heat recoverable article according to any one of claims 1 to 12, a tee-shaped metallic bus bar surrounded by an electrically insulating cross-linked polymeric material, and a heat recoverable polymeric tubing having a one minute electric strength of at least 30 kV/mm.

15. A kit as claimed in claim 14, wherein the crosslinked polymeric material surrounding the tee-shaped bus bar is track resistant.

16. An assembly substantially as hereinbefore described with reference to and as illustrated by Figure 4 of the accompanying drawings.

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1514924 COMPLETE SPECIFICATION
2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 1

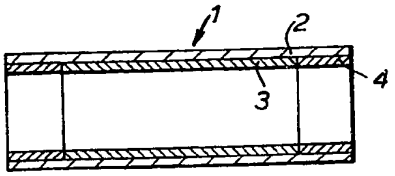

FIG. 1.

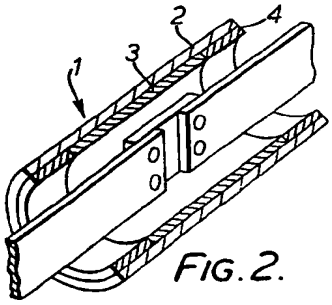

FIG. 2.

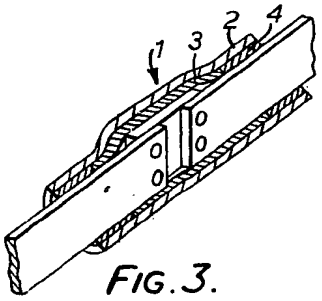

FIG. 3.

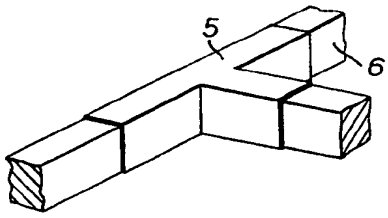

FIG. 4.

1514924 COMPLETE SPECIFICATION
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Sheet 2

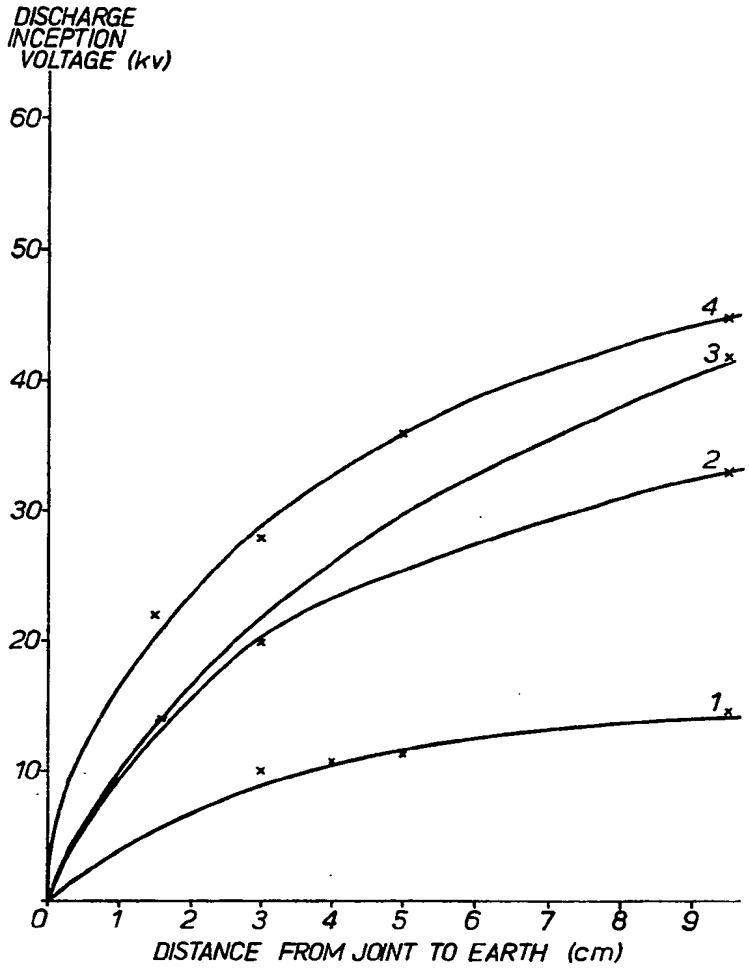

FIG. 5.